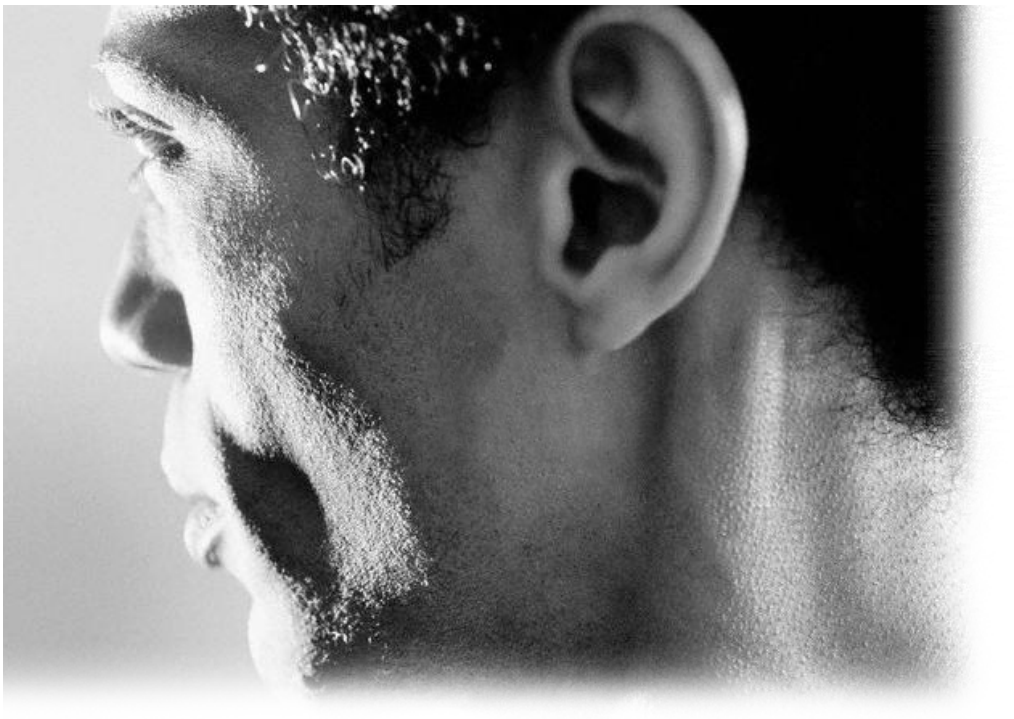
Hearing Conservation

Guidelines



Department of LABOR AND INDUSTRIES

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Contents

Introduction

When hearing is lost because of noise exposure, it cannot be restored. By law, companies whose workers are exposed to high noise levels must have an active program for protecting their employees' hearing.

This book is a guide for employers. It can help you put together a hearing conservation program that conforms to the Washington state standard. It includes a copy of the standard, information on noise protectors, what to monitor and how to evaluate noise levels in your workplace, warning signs to check, record keeping requirements, and ways to train employees to protect their hearing.

By following the methods outlined in this book, you'll be able to prevent hearing loss in your workers and reduce future claims against your industrial insurance account at the same time. A good hearing conservation program also shows your concern for the well being of your workers.

The Department of Labor and Industries will be happy to answer any questions you may have as you put together your program.

Overview of the hearing conservation standard

Excessive sound levels or "noise" (unwanted sound) can produce hearing loss that is temporary, permanent or a combination of temporary and permanent. Since noise-induced loss cannot be repaired or cured, Labor and Industries has adopted permissible exposure limit (PEL[1]) of an eight-hour time-weighted average (TWA) of 85 dB (decibels) for noise measured on the A-scale at slow response. This permissible exposure limit is designed to guard against unnecessary hearing damage. (See WAC 296-62-09015.) Values equal to or below these levels are considered acceptable for industrial noise exposure without the use of hearing protection.

The hearing conservation standard requires the employer to establish an effective hearing conservation program for employees exposed to noise at or above a TWA of 85 dB measured on the A-scale of a sound level meter at slow response or, equivalently, a noise dose of 50 percent as shown on a noise dosimeter.

Incorporated into the PEL is a maximum exposure level or ceiling for noise. Any exposure above the ceiling level mandates the use of hearing protection regardless of the exposure duration. For continuous noise, the ceiling level is any noise above 115 dBA and for impact/impulse noise, the ceiling is at or above 140 dB. (See WAC 296-62-09031.)

The Washington Industrial Safety and Health Act (WISHA) administered by Labor and Industries requires employers covered by WISHA to protect any worker exposed to sound levels greater than the PEL by ensuring the use of hearing protectors (earplugs, muffs) supplied by the employer at no cost to exposed employees. The employer also is required to reduce employees' noise exposure levels through feasible engineering controls and/or administrative controls whenever exposure equals or exceeds an eight-hour TWA of 90 dBA (WAC 296-62-09055).

The employer's hearing conservation program may be a temporary requirement in cases where the company is successful in using engineering or administrative controls to reduce the overall noise level to below 85 dBA, but it must be a permanent and ongoing program in cases where the noise level remains at or above 85 dBA.

[1] The permissible exposure limit refers to a sound pressure (noise) level to which it is believed nearly all workers may be repeatedly exposed throughout their working lifetime without adverse effects on their ability to hear and understand normal speech.

What is an effective hearing conservation program?

An effective hearing conservation program should first assess company wide noise exposures in order to identify any employee or group of employees exposed to noise at or above a TWA of 85 dBA. **For these employees**, the employer must develop, implement and maintain (at no cost to the employees) a program consisting of:

1. Mandatory audiometric testing.
2. Making hearing protectors available and ensuring their use.
3. Comprehensive training explaining hearing loss, hearing protective devices, and the employer's hearing conservation program.
4. Installation of warning signs for high noise areas (115 dBA or higher).
5. Keeping accurate records.
6. Ensuring employee access to their records as specified under WAC 296-62-09041.

Additionally, the employer must post a copy of the hearing conservation standard or post a notice to affected employees or their representatives that a copy of the standard is available at the workplace for their review.

Does my company need a hearing conservation program?

Monitoring

The first step in determining whether your company needs a hearing conservation program is to monitor individual or representative employee noise exposure levels throughout your facility. Extensive monitoring is not necessary if the employer chooses to implement the hearing conservation regulations for all employees; however, monitoring is required to establish the adequacy of hearing protectors and to define boundaries for placement of high noise warning signs.

As you walk through your plant, you will notice some areas are noisier than others, but this is not necessarily a problem. Can you speak to the operators at a comfortable distance (*e.g.* five feet) without raising your voice, or do you have to get within two feet and raise your voice to be understood? If a raised voice or shouting is necessary, you should follow up with a noise survey representative of each employee's actual exposure. The employer must allow affected employees or their representatives the opportunity to observe any monitoring conducted.

Industrial noise is divided into two segments: continuous and impulse/impact noise. Any noise characterized by peaks or maxima at intervals of less than one second (*e.g.* typewriter or rifle shot) or conversely, a noise with a duration of more than one second (a waterfall, pump whine or pile driver) is considered continuous. Noise may contain both continuous and impulse/impact segments (for example: a jump saw). The noise from other machinery (background) or the idling saw may be continuous at one level. But when the saw is activated, a sharp rise in the noise level occurs for a very short duration (less than one second), then this higher level is considered impulsive.

Employee noise exposure is classified as continuous or intermittent. An example of a continuous exposure would be a planer feeder in a sawmill if the operator feeds the planer for the total work shift. The noise exposure would be considered intermittent though, if the operator is exposed for two or more segments at different levels during the day; for example, if he/she rotates with another person who has a different (higher or lower) noise exposure level. The monitoring program must address all noise exposures – continuous, intermittent and impulse/impact noise. These are integrated together to obtain the total noise exposure for the worker.

Measuring employee noise exposure levels in your plant may be accomplished by the use of a sound level meter or noise dosimeter. Both the sound level meter and dosimeter use a microphone to measure sound levels and convert variations into electrical impulses.

These impulses are amplified, then weighted or adjusted by electronic circuits inside the instruments. One circuit, called the A-weighting network of "A scale" is designed to adjust the frequency components of the noise signal to approximate the response or sensitivity the human ear would have to the same signal. Noise levels are averaged by means of a "slow" response mode on the units to compensate for a very short duration signal fluctuations. The sound level meter displays the signal strength or sound pressure level directly as decibels, while the dosimeter displays its value as a percentage (where 50 percent equals the PEL).

Impulse/impact noise can also be measured by these units. At present, the dosimeter requires no modifications; however, the sound level meter must be equipped with an impulse mode or analyzer, and the noise must be measured on the linear scale. When using a sound level meter for screening purposes or actual noise assessment, you will need to collect information on the employee's exposure pattern by timing and measuring exposure levels. The simplest example is where an employee tends a machine (continuous sound level of 100 dBA) for an entire shift (eight hours). This employee would have an 8-hour TWA of 100 dBA.

For intermittent exposures, the employee's total noise dose can be calculated from the sound level meter readings by use of the following formula:

$$D = 100 \ X \left(\frac{C1}{T1} + \frac{C2}{T2} + \ldots \frac{Cn}{Tn}\right)$$

where C equals the amount of time spent at each noise level and T represents the reference duration for that noise level. A value of 50 percent equals 85dB, the level at which a hearing conservation program must be established. If desired, these values can be converted to the employee's TWA by the use of Table E-2 in WAC 296-62-09055, Appendix E. This equation may also be used to evaluate engineering and/or administrative controls.

The value of the noise dosimeter is that the dosimeter automatically accumulates and time-weights noise exposures and stores them, thereby doing all the necessary computations. When the dosimeter is read, it shows the percent noise dose. This value, called the employee's noise dose, can easily be converted to the employee's TWA by the use of Table E-2 (WAC 296-62-09055, Appendix E).

Audiometric testing program

Perhaps the most important aspect of the hearing conservation program is the on-going monitoring of employees' hearing. As you can imagine, there is no enforceable standard which will protect everyone's hearing; therefore, it is important to have reliable audiometric data to identify those individuals who are the most sensitive to noise-induced hearing loss before their hearing is severely impaired. This assessment allows management to protect sensitive workers by placing them in positions with less noise exposure. It also indicates whether the employer's hearing conservation program is

effective and may dictate whether additional measures for employees' hearing protection are necessary.

For audiometric testing to be effective, each employee must have a pre-employment or pre-placement audiogram to act as a baseline to which future annual audiograms will be compared. Baseline audiograms for employees must be preceded by at least 14 hours of "quiet time." If high levels of noise will be encountered (on or off the job) the employer should caution the employee to wear appropriate hearing protection during these periods. If the employee does not receive needed quiet time prior to the hearing test, some temporary hearing loss may still remain. This temporary loss will be recorded on the employee's audiogram; therefore, an accurate representation of the hearing threshold will not be indicated.

The employer's audiometric program must be under the supervision of a licensed or certified audiologist, otolaryngologist, or other qualified physician. Audiograms may be given by a certified technician who is responsible to an audiologist, otolaryngologist, or qualified physician.

Annual audiograms may be conducted at any time during the work shift. If an indication of hearing loss (threshold shift) appears, re-testing at a different time may be required after a thorough review of the worker's audiogram and baseline and the audiometric test room and equipment calibration data.

Whenever a standard threshold shift occurs (an average of 10 dB or more change from the worker's baseline at frequencies of 2k, 3k, and 4kHz in either ear), the employer must comply with WAC 296-62-09027 follow-up procedures.

Audiometric test requirements

The test procedures and equipment specifications are well specified in the standard. Please refer to Appendix VI for the text of the hearing conservation standard.

Hearing protectors

Hearing protectors must be made available to each employee exposed to noise at or above 85 dBA TWA and the employer is required to ensure their use.

Hearing protectors are designed to reduce the noise level at the inner ear. Due to variations in ear canal size and shape and environmental factors such as dust, grease, temperature, and humidity, at least two types of hearing protectors must be available from which employees can choose. The four basic types of hearing protectors are: (1) molded earplugs, (2) custom-molded earplugs, (3) self-molded earplugs, and (4) earmuffs.

Molded earplugs are usually made of plastic or silicone rubber. They are available in a variety of shapes and sizes and are usually characterized by one or more ribs or contours. Molded earplugs are considered multiple use; therefore, they must be cleaned and properly stored after each use. Custom molded plugs are generally made of plastic and are designed from a molded wax insert of the wearer's ears. They are considered multiple use

but cannot be switched ear to ear. Self-molded earplugs are generally made of mineral down or plastic foam and are molded or formed by the wearer. Generally one size fits all and they may be either single or multiple use. Earmuffs are designed to be multiple use and may be designed to be worn with the harness over or behind the head, or below the chin to facilitate hard hats or personal preference. The ear pads can be foam or liquid-filled, and generally one size fits all.

Employee use of hearing protectors will depend primarily on comfort; therefore, special attention should be given to employee feedback. Management/employee cooperation and employee understanding of the potential for hearing loss are also important. See Appendices II and III for additional program ideas.

Hearing protectors must reduce the employee's noise exposure level at the inner ear to 85 dBA or below. Actual noise reduction provided by hearing protectors varies widely; therefore, the employer must ensure employee noise exposure is actually reduced by evaluating the noise reduction provided by each type. (See Appendix V, which contains noise reduction ratings, and Appendix D of the hearing conservation standard, which is located in Appendix VI.)

The employee's hearing protection should be re-evaluated whenever noise exposure increases (he/she moves to a noisier job) to assure that the type of protection selected will still reduce the employee's time-weighted average to 85 dBA. If hearing protectors are to provide the intended attenuation, they must be worn as designed and instructed. Any modification or use not authorized or approved by the manufacturer may render them ineffective. For example, knit wool "watch caps" under earmuffs will not allow a proper ear-cup-to head seal.

Similarly, cutting off a portion of an earplug or not inserting it properly will reduce its effectiveness drastically. Remember, hearing protectors must be comfortable to be worn, and must be properly worn to be effective.

For similar reasons, radio earphones (those not specifically designed for employee communication) are not allowed as protection from excessive noise levels. Actual noise reduction of most brands is relatively poor, and workers tend to "cover up" or mask outside noise by turning up the radio volume.

Training

Investigations indicate that only a fraction of those exposed to excessive noise in industry wear hearing protection. Of those, only a few use hearing protection properly and for the entire time they are exposed. How many times have you seen employees removing their earplugs or muffs to talk to a buddy? Obviously the employer's training program is especially important. Employees must recognize the potential for noise-related hearing loss and that an effective hearing conservation program will reduce that potential. Proper employee training also helps reduce the overall cost of program administration and operation since follow-up by management and supervisors will be reduced, and equipment and supplies will be more efficiently used and maintained by employees.

Initial employee training should be conducted prior to receiving the baseline audiogram so employees can fully understand the purpose of the program and their audiogram. Once understood, the audiogram will become one of the most important motivating measures for the employee because it shows actual hearing ability. The training program must comply with the requirements of WAC 296-62-09035.

After the initial training is complete, required annual training will reinforce employee understanding and appreciation of the noise problem and will allow the employer to update the training to reflect changes in hearing protection equipment, work processes, and the company's noise abatement programs (if applicable). This is an excellent time for employee input since many times the employee is more aware of a problem with a specific machine or process and may have useful ideas for reducing his or her own noise exposure.

Informative material in audio-visual and/or printed form is available from several hearing protection manufacturers. You may also want to contact local safety equipment supply dealers or neighboring industries to see copies of their training programs for additional ideas.

Posted warning signs

Warning signs must be posted at entrances to or at the periphery of all well-defined work areas in which employees may be exposed to 115 dBA or more. Warning signs must clearly indicate that the area is a high noise area and that hearing protectors are required. Signs are available from several hearing protection manufacturers and local safety equipment supply dealers. Many companies supplement their sign program by developing noise maps on which various noise zones are marked in different colors. These maps may be posted at all entrances or in lunchrooms so that the workers are aware of the various areas inside the plant where hearing protection is required.

Record keeping

The employer must keep accurate records of all employee exposure monitoring and audiometric testing data, including equipment calibration and test room background levels.

Employees exposure monitoring records include time-motion studies, sound level meter results, dosimeter results, equipment identification (model number, serial number) and calibration data. These records must be maintained for at least two years. Longer retention will prove beneficial in cases where engineering controls and/or administrative procedures are being instituted and evaluated.

Audiometric testing data includes employee name and job classification, employee audiograms, date of audiogram, examiner's name, date and type of the last audiometric calibration, and employee's most recent noise exposure assessment. Data on background sound pressure levels inside the test room must also be retained. Audiometric testing data must be retained for the duration of the affected employee's employment.

All records required by this section shall be provided upon request to employees, former employees, employee representatives and the director of the Department of Labor and Industries or his or her designee. The provisions of WAC 296-62-052 through 296-62-05223 also apply to records required under the hearing conservation standard.

If an employer ceases to do business, they shall transfer all required records to the successor employer. The successor employer shall retain these records according to WAC 296-62-09041(4).

Audiometric measurement instruments

The hearing conservation standard includes Appendices A, B, C, D and E which address audiometric measurement instruments, audiometric test rooms, acoustic calibration of audiometers, methods of estimating the adequacy of hearing protector attenuation, and noise computation. Although the standard is technically written, those administering the hearing conservation and/or audiometric program should be familiar with the material.

Technical assistance

If you need help in understanding or implementing any portion of the hearing conservation standard, please contact the Labor and Industries office closest to you. Ask for Industrial Hygiene Consultation Services.

Everett	(425) 290-1300
Seattle	(206) 281-5400
Spokane	(509) 324-2600 or 1-800-509-8847
Tacoma	(253) 596-3800
Tumwater	(360) 902-5799
Vancouver	(360) 896-2300
Yakima	(509) 454-3700 or 1-800-354-5423

References

1. **American National Standards Institute, 1430 Broadway, New York, NY 10018**

   - Specification for Personal Noise Dosimeters, S1.25, 1978
   - Specification for Sound Level Meters, S1.4, 1971 (R 1976)

2. **Bilsom International, Incorporated, 11800 Sunrise Valley Drive, Reston, VA 22091**

   - Some Practical Information on Noise and Hearing Protection
   - Guidelines for Hearing Conservation Programs
   - The Danger of Evaluating Hearing Protectors on their Attenuation Alone
   - Hearing Cell Survival Campaign
   - In Defense of Hearing
   - Saving People's Hearing Cells

3. **EAR Division, Cabot Corporation, 7911 Zionsville Road, Indianapolis, IN 46268 Hearing and Hearing Protection, a seminar presented by EAR Corporation including:**

   - EAR Logs 1 through 8
   - Elements of a Hearing Conservation Program
   - General Guidelines for Developing an Effective Hearing Conservation Program for Industrial Environments

4. **United States Environmental Protection Agency, Office of Noise Abatement and Control, Standards and Regulations Division (ANR-490), Washington, D.C. 20460**

   - Voluntary Product Noise Labeling (Fact Sheet)
   - General Provisions for Product Noise Labeling (Fact Sheet)
   - Noise Labeling Requirements for Hearing Protectors (Backgrounder)
   - Environmental News, Wednesday, September 12, 1979
   - General Provisions for Product Noise Labeling and Noise Labeling Requirements for Hearing Protectors; Approval and Promulgation, Federal Register, Volume 44, Number 190, Friday, September 28, 1979

A Sound Hearing Conservation Program Saves You Money, 1982, Tracor Incorporated, 6500 Tracor Lane, Austin, TX 78721

Hearing Loss—Hope through Research, National Institute of Health, DHEW Publication Number (NIH) 73-57, Bethesda, MD 20014

Appendix I
Noise level computation

See Appendix VI for applicable equations and conversion tables.

Example 1.

Assume an employee is exposed to 92 dBA for eight hours. Compute the employee's noise exposure, the time-weighted average and what action, if any, would be required of the employer.

1. Exposure
   Dose = 100 (C_2/T_1) = 100 (8/6) = 133 (133 %)
   T_1 is obtained from Table E-1 in Appendix E, WAC 296-62-09055.

2. Time-weighted Average
   In the conversion table in Appendix VI, find the values for 130% and 135%. The difference in the time-weighted average values (92.2 - 91.6) equals 0.6. Since 133% is 3/5 of the way between 130 and 135, 133% equals 3/5 (0.6) + 91.6 = 92 dBA.

3. Employer Action
   Since the employee's exposure is above the 85 dBA PEL and the 90 dBA action level for administrative and engineering controls, the employer would be required to institute both a hearing conservation program and feasible engineering and/or administrative controls. Additionally, since the employee is above the PEL, hearing protectors would be required.

Example 2.

Assume a continuous noise exposure for an employee of 90 dBA and a work shift of 8 a.m. to 4: 30 p.m. with a 15-minute morning and afternoon break and a 30-minute lunch. Both breaks and lunch are in an area with less than 70 dBA exposure. (Although this exposure could be integrated into the employee's total noise exposure, it is not significant and will not be considered in these calculations.) Calculate the worker's exposure, TWA, and the employer's responsibility.

1. Exposure
   Actual exposure (subtracting the lunch time and work breaks from the employee's work shift) indicates a 90 dBA exposure for 7 ½ hours. D = 100 (C_1/T_1) = 100 (7.5/8) = 94 (94%)

2. Time-weighted Average
   From Table E-2 a noise exposure of 94% converts to a time-weighted average of 89.6 dBA.

3. Employer Action
   Since the employee's time-weighted average is between 85 and 90 dBA, a hearing conservation program must be developed and maintained for the employee. Engineering and/or administrative controls are not required, but may be beneficial, since the hearing conservation program would no longer be required if the employee's TWA were reduced below 85 dBA.

Example 3.

Assume a technician works in a noise enclosure booth with a noise exposure of less than 70 dBA. The technician makes rounds to read gauges and instruments that are located in an area with a noise level of 105 dBA. The technician makes four trips a day, and each trip lasts 30 minutes. Calculate the employee's noise exposure, TWA and employer's responsibility.

1. Exposure
   With four trips a day and 30 minutes per trip, the employee is basically exposed to two hours of noise at 105 dBA with the remaining time spent inside the booth.
   $D = 100 (C_1/T_1) = 100 (\frac{2}{1}) = 200$ (200%).

2. Time-weighted Average
   The employee's TWA from Table E-2 in Appendix VI is 95 dBA.

3. Employer Action
   Since the employee's noise exposure is above the PEL and the 90 dBA action level, both a hearing conservation program and feasible engineering and/or administrative controls must be introduced.

Example 4.

Assume a timber trimsaw operator with a background noise level inside the operator's booth of 85 dBA, cuts one timber every 10 seconds with a noise exposure during the cut of 105 dBA for three seconds. The employee works from 6 a.m. to 4:30 p.m. and has a 15-minute break in the morning and the afternoon and a 30-minute lunch break, all of which are below 70 dBA. Calculate the employee's noise exposure and TWA.

1. Exposure
   The employee is exposed to 105 dBA for 3 seconds, then 85 dBA for the remaining 7 seconds. This cycle continues throughout the work day. (The employee's breaks and lunch time are spent below 70 dBA; therefore, these values will not significantly affect noise exposure.) The employee has a noise exposure of 9½ hours. Thirty percent (30%) of this time (3 out of every 10 seconds) is spent at 105 dBA and the remaining 70% is spent at 85 dBA. The total exposure equals 0.3 (9.5 hours X 60 minutes/hour) = 171 minutes at 105 dBA + 0.7 (9.5 hours X 60 minutes/hour) = 399 minutes at 85 dBA. C_1 = 171 minutes, T_1 = 60 minutes (1 hour), C_2 = 399 minutes, T_2 = 960 minutes (16 hours), therefore,

$\frac{C_1}{T_1} + \frac{C_2}{T_2} = \frac{171}{60} + \frac{399}{960}$ and $D = 100 \left(\frac{171}{60} + \frac{399}{960}\right) = 327$ (327%).

2. Time-weighted Average
   From the conversion table we find a noise dose of 327% lies between 320 and 330 with values of 98.4 dBA and 98.6 dBA respectively.

   320% = 98.4 dBA
   330% = 98.6 dBA
   327% = (7/10) (0.2) + 98.4 = 98.5

Example 5.

Assume a security guard works an eight-hour shift and makes eight rounds a night with the following exposure each round: 20 minutes inside Building A with a noise exposure of less than 70 dBA; 30 minutes in Building B which has a cyclic machine operation where the noise levels are 100 dBA for 3 seconds (30%), 95 dBA for 3 seconds (30%) and 90 dBA for 4 seconds (40%); the yard for the remaining 10 minutes of the round with a noise exposure of 85 dBA. Calculate the employee's noise exposure and time-weighted average.

Since the employee's noise exposure in Building A is less than 70 dBA, this exposure is not significant and will not enter into the computation. In Building B we find three noise exposures, 100, 95, and 90 dBA respectively. The yard also has an exposure (85 dBA) which will enter into the total computation.

Calculating the partial exposures at each noise level we find:

At 100 dBA

$$30\% \times \frac{30 \text{ minutes}}{\text{round}} \times \frac{8 \text{ rounds}}{\text{shift}} = \frac{72 \text{ minutes}}{\text{shift}}$$

At 95 dBA

$$30\% \times \frac{30 \text{ minutes}}{\text{round}} \times \frac{8 \text{ rounds}}{\text{shift}} = \frac{72 \text{ minutes}}{\text{shift}}$$

At 90 dBA

$$40\% \times \frac{30 \text{ minutes}}{\text{round}} \times \frac{8 \text{ rounds}}{\text{shift}} = \frac{96 \text{ minutes}}{\text{shift}}$$

The yard at 85 dBA

$\frac{\text{10 minutes}}{\text{round}} \times \frac{\text{8 rounds}}{\text{shift}} = \frac{\text{80 minutes}}{\text{shift}}$

The employee's total noise exposure can be calculated from the noise exposure formula where $C_1 = 72$, $T_1 = 120$, $C_2 = 72$, $T_2 = 240$, $C_3 = 96$, $T_3 = 480$, $C_4 = 80$, $T_4 = 960$.

The employee's total noise exposure =

$$100 \left(\frac{C_1}{T_1} + \frac{C_2}{T_2} \ldots \frac{C_n}{T_n}\right) = 100 \left(\frac{72}{120} + \frac{72}{240} + \frac{96}{480} + \frac{80}{960}\right) = 118\ (118\%)$$

Summary

As you can see, the more variable the noise sources or exposure times, the more involved the computations become. Noise dosimeters overcome this problem by electronically accumulating and integrating the noise signals into the employee's noise dose. Additional time can be saved because several dosimeters can be observed by one person; however, a simultaneous survey using a sound level meter must be conducted to support the dosimeter results.

Appendix II

How to make your hearing conservation program work

The most difficult part of a hearing conservation program is getting employees to accept and wear hearing protectors regularly. It is absolutely necessary to have the full support of all levels of management, especially supervisors who must encourage and enforce the wearing of hearing protectors. Supervisors should be the first to be provided with hearing protectors and proper training so that they themselves can be assured of the benefits and effectiveness of hearing protectors.

Exposed employees must also be convinced of the necessity of wearing hearing protection, and this is usually the most difficult task of all. EAR LOG 8 in Appendix IV (courtesy EAR Division, Cabot Corporation) lists a number of excuses employees give for not wearing hearing protection and also lists what has happened in these instances. Instead of arguing about the excuses, it is much better to explain the dangers of excessive noise exposure—for example, that hearing cells inside the ear can become irreparably damaged and what it means to lose one's hearing.

Employees can be encouraged to wear hearing protectors by pointing out their advantages:

1. Hearing protectors will prevent permanent hearing damage. In cases where a hearing loss already has been suffered, further damage will be prevented.
2. Hearing protectors will prevent temporary hearing loss and tinnitus (ringing of the ears). An employee who wears hearing protectors will hear much better after work, enabling better enjoyment of family life and activities such as TV viewing. Additionally, the employee will not be annoyed as much by ringing of the ears after a noisy work day.
3. Wearing hearing protectors in steady noise will usually allow an employee to hear speech at least as well as without protectors.

Hearing protectors generally will not impair the ability to hear any warning sounds or signals that normally would be heard without them. Properly worn, hearing protectors will prevent chips, dirt, and other foreign material from entering the ear, thereby reducing the possibility of injury or infection. Hearing protectors must be kept clean, which means changing them when needed (for disposable earplugs) or cleaning and proper storage (for reusable earplugs and earmuffs).

Remember, you as the employer have the obligation and duty to help your workers protect their hearing. You must know and understand the hazards of noise exposure and understand how noise induced hearing loss occurs. You must also be able to persuasively inform your employees that noise-induced hearing loss cannot be cured and the effects of

noise are cumulative; therefore, early detection of any damage to an employee's hearing through the company's audiometric program is essential.

Encourage and reward positive influences from employees. Give workers a choice of hearing protectors. Let them pick the most comfortable type from several different styles which are applicable to their exposure. Make hearing protectors easily available throughout the work site. Encourage and support your employees initially through the acclimation period and follow-up. Unfortunately, you must also consider a disciplinary policy for a problem worker. Most of all, set a good example. Create an attitude of trust and be interested in your workers' health.

Additional assistance is available from equipment manufacturers and safety equipment supply companies who distribute hearing protection devices and equipment. Many times they have special expertise and may be of direct value to you. They may also be able to supply samples and training material. You should also contact similar industries in your area and work with your trade associations for ideas about implementing your program.

Finally, count on your employees. Many times they can be unusually inventive and may have specific ideas to control their own noise exposure. Consider an idea box and incentive program. Remember, if the noise exposure level is reduced below 85 dBA, your employees will be protected and no hearing conservation program will be necessary.

Appendix III

Outline of a sample hearing conservation training program

I. Introduction

A. An overview of the purpose of the training session.
   1. Identify expected outcomes.
   2. Introduce program personnel and their responsibilities.

B. Explain the noise survey.
   1. Identify noise sources.
   2. Identify job classifications at risk.
   3. Evaluate and explain the extent of the hazard.

C. Explain the company's hearing conservation policy.
   1. Note company efforts at engineering controls.
   2. State company policy regarding HCP and disciplinary program.
   3. Emphasize employee involvement and participation.

II. Noise

A. Identify what noise is.
B. Identify where noise is found, both on and off the job.
C. Explain hearing physiology.
D. Explain what noise does to your hearing.
   1. Identify difference between temporary and permanent threshold shifts.
   2. Include the other physical effects of noise (headaches, fatigue, stress, etc.)
   3. Make it clear, "you don't get used to noise, you just lose your hearing."

III Hearing Protectors

A. Why use hearing protectors?
   1. How and why they work.
   2. Explain noise reduction rating for different types.
   3. Use examples to demonstrate the difference between partial and full shift wear.

B. Adjustment period to hearing protectors.
   1. It takes a few days to get used to the "different" sounds heard in the workplace.
   2. Jobs that require a worker to "listen" to a machine can still be done once the worker gets used to the protectors.

3. Speech is not interfered with (unless a worker has a significant existing loss in the speech frequencies).
4. Discomfort from hearing protectors in or covering the ear.

IV. The company's hearing conservation program

A. What types of hearing protectors are available?

B. Why were they chosen?
    1. What conditions in the workplace make one type preferable over another?

C. Each worker will be fitted individually, at which time they must be instructed in:
    1. Proper placement and seating of the hearing protectors.
    2. Limitations of each hearing protector type.
    3. Proper care of hearing protectors (manufacturer's directions should be followed.)

D. Audiometric testing
    1. Test hearing to monitor effectiveness of the hearing conservation program.
    2. Explain test procedure and results.
    3. Explain who will do the test and who can see the records.
    4. Explain that testing does not improve, save, or protect worker's hearing.

E·A·R·LOG® 3

Third in a comprehensive series of technical monographs covering topics related to hearing and hearing protection.

The Effects of Hearing Protectors on Auditory Communications

BY ELLIOTT H. BERGER
Senior Scientist, Auditory Research

In EARLogs[1] #1 and #2 we have demonstrated and discussed the fact that hearing protective devices (HPDs) reduce user sound exposures when properly worn. This means that all sounds may be attenuated, both unwanted sounds (noise) and useful sounds such as speech and warning signals. Thus wearing HPDs may affect speech discrimination, and the perception of warning signals. The magnitude and quality of these effects as a function of hearing level and hearing protector type are summarized in this, EARLog #3.

Speech Discrimination

Speech discrimination (SD) is a measure of one's ability to understand speech. It is greatly affected by such factors as a person's hearing acuity, the signal (speech) - to - noise ratio, the absolute signal levels, visual cues (lip and hand motion), and the context of the message set. SD is measured by presenting to subjects one of a number of prepared word lists (available in the literature), and determining what percentage correct responses they achieve[2]. The effects of HPDs on SD can be evaluated by establishing a set of test conditions, and measuring SD with and without HPDs on the subjects. The results of such tests conducted by many investigators may be summarized as follows:

1. HPDs have little or no effect on the ability of normal hearing listeners to understand speech in moderate background noise [3,4,5,6,7] $\approx$80 dBA, but HPDs begin to decrease SD as the background noise is reduced even further. HPDs will decrease SD for hearing impaired listeners[8] in low-to-moderate noise situations.

2. At high noise levels $\geqslant$ 85 dBA HPDs actually improve SD for normal hearing listeners[3,5,9,10,11,12] This is clearly demonstrated in Figure 1[7]. For hearing impaired listeners the effect of HPDs on SD at these high noise levels is not unequivocal, but the results seem to indicate no significant effect.[13]

3. The literature is not extensive enough to differentiate between the effects of earmuffs and earplugs on SD. Nevertheless it may be said that the higher attenuation devices, be they ear muffs or earplugs, offer greater potential for degrading SD at lower sound levels.

The beneficial effects of HPDs on SD can be partially explained by referring to Figure 2 in which the spectrum of a male voice is superimposed upon a typical industrial noise spectrum of 91 dBA. Note that although the HPD's attenuation increases with increasing frequency, at any one frequency both the speech and the noise are reduced equally. The signal to noise ratio is constant, but importantly the overall signal level is reduced. This prevents the ear itself from distorting the signal, a phenomenon which occurs even at levels well below 90 dBA.[14] Thus as long as the speech signal is maintained above audibility, intelligibility can be improved by restricting signal levels to those that will not overload the ear.

The preceeding generalizations may be modified in practice by three important factors. Typically, in real work environments, communications will be accompanied by visual cues and/or be limited in scope. Missed words can be "filled in" and intelligibility maintained. Howell and Martin [5] have shown that when the person speaking wears HPDs his speech quality is degraded and this will adversely effect communications. And finally, Acton[15] has demonstrated that employees get accustomed to listening in noise and can perform better with respect to SD than do laboratory subjects with equivalent hearing levels. The interaction of these three effects has not been fully evaluated by any one author, but Rink[3] has shown that visual cues do improve SD for hearing impaired persons wearing HPDs, especially in noise.

Localization

Another effect that HPDs can have is to confuse one's ability to locate the direction of origin of sounds.[16,17] The data indicate that earmuffs, which necessarily cover the entire ear, can interfere with this localization accuracy whereas inserts, which generally leave virtually the entire outer ear exposed, do so to a much lesser extent. Furthermore, experiments with earmuffs[18] indicate that subjects cannot adapt to this effect, i.e., they cannot learn to compensate for the adverse effects of the muff.

Amplitude Sensitive Insert Hearing Protectors

Amplitude sensitive or nonlinear inserts are designed to provide attenuation that increases with increasing sound level, so that for low level noise conditions there is little attenuation and SD can be improved. Basically these devices are insert protectors provided with a small orifice running longitudinally through the body of the plug. The orifice may contain valves or acoustical damping materials.

At sound levels below $\approx$110 dB[19] these devices simply behave as a vented earmold with almost no attenuation below 1 kHz and attenuation increasing to as much as 30 dB at higher frequencies.[20] At high sound levels ($\geqslant$140 dB), steady-state or impulsive sound waves generate turbulent air flow in the orifice which impedes the passage of sound. Measurements[19] of gunfire impulses in cadaver ears have

SPEECH DISCRIMINATION AS A FUNCTION OF NOISE LEVEL AND SPEECH LEVEL, FOR EARPLUGS vs. NO EARPLUGS

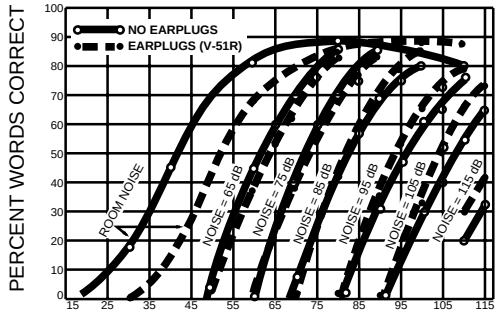

Figure 1

The relationship between speech discrimination and speech level with noise level as a parameter. Each point represents an average of the % correct responses for 8 subjects to a list of 200 words read over a PA system in a reverberant room. From Kryter.[7]

EXAMPLE OF THE REDUCTION OF SPEECH AND NOISE LEVELS THROUGH THE USE OF A PREMOLDED INSERT HEARING PROTECTOR

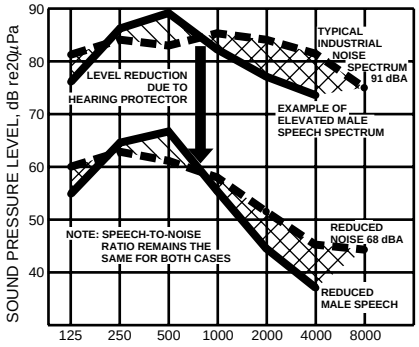

Figure 2

verified that the peak noise reduction increases from approximately 10 dB for 140 dB peaks to 20 dB for 180 dB peaks, for one particular nonlinear device. Combining this information with impulse noise damage risk criteria[10,21] indicates that these devices should be effective for limited exposures (⩽20 rounds per session) to gunfire noise up to ≈175 dB peak SPL. Measurements[19,22,23,24] of the temporary (hearing) threshold shifts of human subjects exposed to such noise, in non-reverberant spaces, verify this supposition. Unfortunately these devices are of little value for many occupational and recreational noise exposures wherein the noise levels are rarely the appropriate type or of sufficient level for these devices to become functional.[25]

Summary

The preceeding data indicate that HPDs can be effectively utilized for the preservation of hearing in high noise level environments with minimal effects on SD. For hearing impaired persons, the utilization of HPDs in lower noise level environments should be carefully considered. If localization capabilities are important then inserts should be chosen instead of earmuffs. And finally, the use of amplitude sensitive devices may be advantageous for use on firing ranges where they have been shown to provide adequate protection for limited exposures.

References and Footnotes

1. Berger, E.H. The EARLogs, complete series is available upon request from Aearo Company.
2. Rintelmann, W. F. (1979). Hearing Assessment. University Park Press Baltimore, MD.
3. Rink, T.L. (1979). Hearing Protection and Speech Discrimination in Hearing-Impaired Persons. Sound and Vibration, Vol. 13 No.1, 22-25.
4. Coles, R. R. A. and Rice, C. G. (1965). Earplugs and Impaired Hearing. J. Sound Vib., Vol. 3, No. 3, 521-523.
5. Howell, K. and Martin, A. M. (1975). An Investigation of the Effects of Hearing Protectors on Vocal Communication in Noise. J. Sound Vib., Vol. 41, No. 2, 181- 196.
6. Lindeman, H. E. (1976). Speech Intelligibility and the Use of Hearing Protectors. Audiology, Vol. 15, 348-356.
7. Kryter, K. D. (1946). Effects of Ear Protective Devices on the Intelligibility of Speech in Noise. J. Acoust. Soc. Am., Vol. 18, No. 2, 413-417.
8. Hearing impairment in this context may be approximated as an HTL averaged over 2k, 3k, 4 kHz that is ⩾ 35dB.
9. Acton, W. I. (1977). Problems Associated with the Use of Hearing Protection. Ann. Occup. Hyg., Vol. 20, 387-395.
10. Kryter, K.D. (1970). The Effects of Noise on Man. Academic Press, New York, NY.
11. Rice, C. G. and Coles, R. R. A. (1966). Design Factors and Use of Ear Protection. Brit. J. Industr. Med., Vol. 23, 194-203.
12. Michael, P.L. (1965). Ear Protectors - Their Usefulness and Limitations. Arch. Env. Health, Vol. 10, 612-618.
13. Gasaway, D.C. (1979). Personal communication. In most Air Force communication systems the proximity of the microphone to the speaker's lips alters the frequency balance of speech in a way that insures that HPDs will almost always improve SD, even for hearing impaired individuals.
14. Lawrence, M. and Yantis, P.A. (1956). Onset and Growth of Aural Harmonics in the Overloaded Ear. J. Acoust. Soc. Am., Vol. 28, 852-858.
15. Acton, W.I. (1970). Speech Intelligibility in a Background Noise and Noise-Induced Hearing Loss. Ergonomics, Vol. 13, No. 5, 546-554.
16. Atherly, G. R. C. and Noble, W. G. (1970). Effect of Ear - Defenders (ear muffs) on the Localization of Sound. Brit. J. Industr. Med., Vol. 27, 260-265.
17. Noble, W.G. and Russell, G. (1972). Theoretical and Practical Implications of the Effects of Hearing Protection Devices on Localization Ability. Acta Otolaryng., Vol. 74, 29-36.
18. Russell, G. (1977). Limits to Behavioral Compensation for Auditory Localization in Earmuff Listening Conditions. J. Acoust. Soc. Am., Vol. 61, No.1, 219-220.
19. Forrest, M. R. and Coles, R. R. A.(1970). Problems of Communications and Ear Protection in the Royal Marines. J. Royal Naval Med. Service. Vol. 56, No. 1-2, 162-169.
20. EARCAL℠ Laboratory internal research notes, N2460 33, (1979).
21. Coles, R. R. A., Garinther, G. R., Hodge, D. C. and Rice, C. G. (1968). Hazardous Exposure to Impulse Noise. J. Acoust. Soc. Am., Vol. 43, No. 2, 336-343.
22. Mosko, J. D. and Fletcher, J. L. (1971). Evaluation of the Gundefender Earplug: Temporary Threshold Shift and Speech Intelligibity. J. Acoust. Soc. Am., Vol. 49, No. 6, (Part 1) 1732- 1733.
23. Johnston, J. (1976). Hear and Now. Gun World. April issue.
24. Coles, R.R.A and Rice, C.G. (1968). Speech Communications Effects and TTS Reduction Provided by V51R and Selectone-K Earplugs Under Conditions of High Intensity and Impulsive Noise. J. Sound Vib., Vol. 4, No. 2, 156- 171.
25. Harris, J. D. (1979). Personal communication.

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Fifth in a comprehensive series of technical monographs covering topics related to hearing and hearing protection.

Hearing Protector Performance: How They Work - and - What Goes Wrong in the Real World

BY ELLIOTT H. BERGER
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In previous EARLogs[1] we have discussed how to measure and rate the attenuation of hearing protection devices (HPDs) in the laboratory, how these devices affect auditory communications, and perhaps most importantly how HPDs perform in real world (RW) environments. It was found that laboratory attenuation measurements significantly overestimate the RW performance of HPDs, due to the unrealistic, optimized manner in which experimental subjects can wear these devices for short duration tests. In this, EARLog #5, we will examine these concepts further by analyzing how a correctly worn HPD operates and how its effectiveness is compromised by misuse, misfitting, HPD aging, and abuse.

Sound Transmission to the Unoccluded Ear

The hearing mechanism can be divided into three parts as shown in Figure 1. These are the outer, middle and inner ear. Sound (airborne vibration) is received by the outer ear. The incident sound propagates along the auditory canal, setting the eardrum (tympanic membrane) into motion. The eardrum motion is transmitted via the tiny middle ear bones (ossicular chain) to the inner ear, a liquid filled cavity of complex shape lying within the bony structure of the skull. This causes the liquid in a portion of the inner ear, the cochlea, to vibrate. Membranes and hair cells inside the cochlea, which are very sensitive to this vibration, generate electrical impulses when appropriately stimulated. The impulses are transmitted along the auditory nerve to the brain, where they are "decoded ". The result is the sensation, sound.

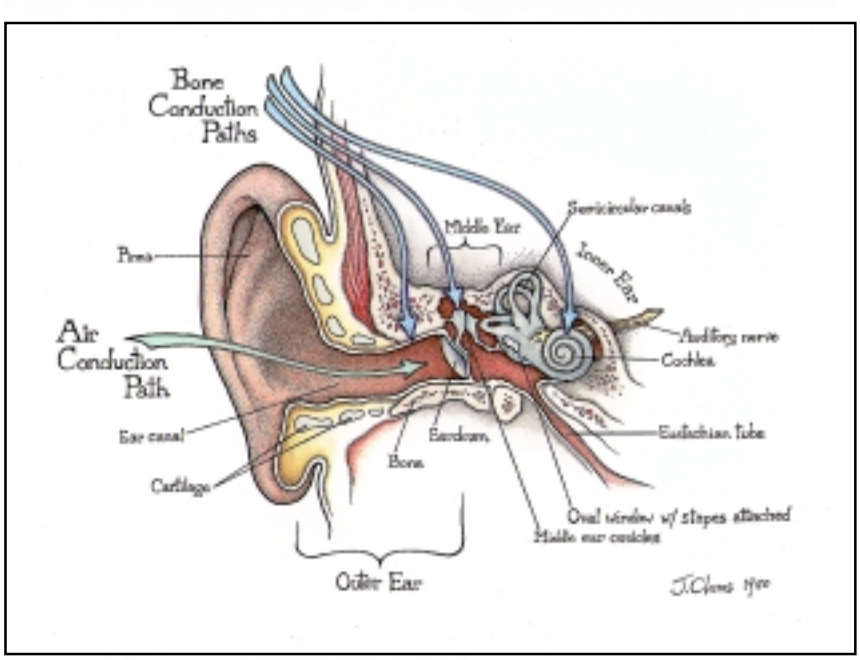
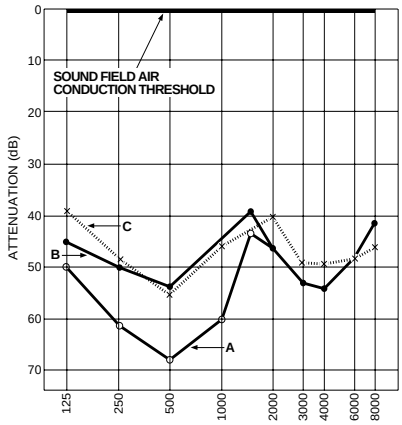


FIGURE 1. Basic Anatomy of the Ear with Illustration of the Air Conduction and Bone Conduction Sound Paths.

When the vibration that excites the cochlear hair cells is the result of the chain of events described above, this is called air conduction. When sound directly vibrates the skull and/or excites vibration of the ear canal walls which in turn stimulates the cochlea, it is called bone conduction. The final sense organ, the cochlea, is the same in either case, only the path of excitation has changed. Since most sound and/or vibration sources will excite both transmission paths, the ear will usually receive both air conducted and bone conducted signals simultaneously.

For the normal hearing individual, the unoccluded ear's bone conduction (BC) sensitivity is much poorer than its corresponding air conduction (AC) sensitivity as shown in Figure 2, curve A. For example at 1000 Hz the sensitivity of the ear is 60 dB poorer for the BC path than for the AC path. This means that even if the AC path were totally eliminated by a HPD, that the ear's sensitivity would only be approximately 60 dB worse, i.e. a "perfect" HPD could only offer 60 dB of attenuation at 1 kHz. Even if the entire head was acoustically shielded, the loudness level of the sound would only

BONE CONDUCTION TO AIR CONDUCTION RATIO IN dB AND THE ATTENUATION FOR AN EARPLUG/EARMUFF COMBINATION.



A — Ratio of Bone Conduction to Air Conduction Thresholds for Open Ear Canals (after Zwislocki[4]).

B — Ratio of Bone Conduction to Air Conduction Thresholds for Occluded Ear Canals (after Zwislocki[4]).

C — Real-Ear Attenuation (ANSI S3.19-1974) for Deeply Inserted E-A-R Plug in Combination with David Clark 19A Earmuff. 5 Subjects.[9]

Figure 2

be reduced by an additional 10 dB to ≅ 70 dB below the unoccluded AC threshold.[2] In this latter case, the conduction path would be from the chest cavity thru the neck to the head.

Sound Transmission to the Occluded Ear

The utilization of a HPD modifies the AC and BC paths discussed in the previous section. Four distinct sound pathways can now be distinguished as shown in Figure 3. There are:

1. Air Leaks - For maximum protection the device must make a virtual air tight seal with the canal or the side of the head. Inserts must accurately fit the contours of the ear canal and earmuff cushions must accurately fit the areas surrounding the external ear (pinna). Air leaks can typically reduce attenuation by 5-15 dB over a broad frequency range.[3]
2. Vibration of the HPD - Due to the flexibility of the ear canal flesh, earplugs can vibrate in a piston-like manner within the ear canal. This limits their low frequency attenuation. Likewise an earmuff cannot be attached to the head in a totally rigid manner. Its cup will vibrate against the head as a mass/spring system, with an effective stiffness governed by the flexibility of the muff cushion and the flesh surrounding the ear, as well as the air volume entrapped under the cup. For earmuffs, premolded inserts and foam inserts these limits of attenuation at 125 Hz are approximately 25 dB, 30 dB and 40 dB, respectively.
3. Transmission thru the Material of the HPD - For most inserts this is generally not significant, although with lower attenuation devices such as cotton or glassdown, this path is a factor to be considered. Because of the much larger surface areas involved with earmuffs, sound transmission thru the cup material and thru the earmuff cushion is significant, and can limit the achievable attenuation at certain frequencies.
4. Bone Conduction - Since a HPD is designed to effectively reduce the AC path and not the BC path, BC may become a significant factor for the protected ear.

When the ear is occluded with an insert or a muff the BC path is enhanced relative to the unoccluded ear for frequencies below 2 kHz. This is called the earplug effect [4, 5] or more generally the occlusion effect.[6,7] This can be easily demonstrated by plugging one's ear canals while speaking aloud. When the canals are properly sealed or covered, one's own voice takes on a bassy, resonant quality due to the amplification of the BC path by which a talker partially hears his own speech. This amplification of BC vibrations results in the differences between curves A and B in Figure 2. Curve A represents the threshold of hearing for BC vibrations with open ear canals, whereas curve B is the threshold of hearing for BC vibrations with the ear canals tightly covered or plugged.

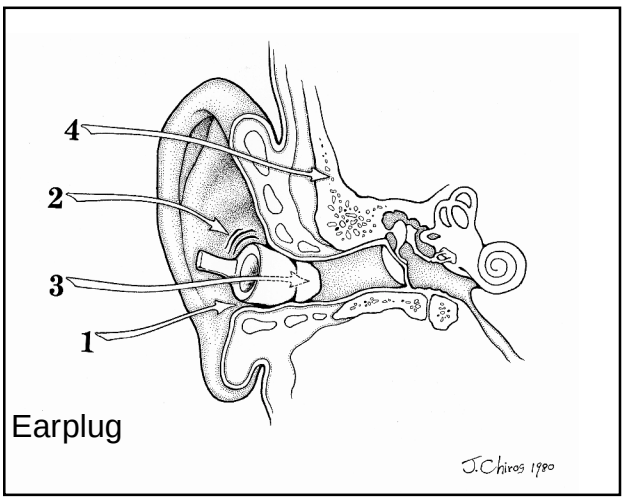
Thus, curve B gives the estimated maximum protection achievable by covering and/or plugging the ears.

A common myth concerning HPDs is that as the sound level increases BC sound becomes more important, and therefore an earmuff will provide better protection than an earplug at higher sound levels. The inaccuracy of this statement is demonstrated by the fact that the relationship between the AC and BC thresholds, as shown in Figure 2, is not dependent on sound level. Any BC advantage that muffs may have over inserts will be independent of sound level, and will be apparent in a standard threshold level attenuation test such as ANSI S3.19-1974.

Due to the occlusion effects and BC limitations described above, as well as other physical considerations, using muffs and inserts in combination does not yield attenuation values that are merely the arithmetic sum of their individual values. In some cases, at some frequencies, almost no improvement will be noted when inserting a pre-molded insert under a muff.[8] Alternatively for other combinations, not fully defined at this time, better results may be achieved. Curve C in Figure 2 demonstrates performance for a deeply inserted E-A-R Plug used in conjunction with a David Clark 19A earmuff.[9] This combination probably represents the highest practical attenuation achievable with currently available HPDs.

Why HPDs Fail in the Real World

When a HPD is properly sized and carefully fitted and adjusted for optimum performance on a laboratory subject, air leaks will be minimized and paths 2, 3 and 4 will be the primary sound transmission paths. In the RW work environment, this is usually not the case, and path 1, sound transmission thru air leaks, often dominates. Air leaks arise when plugs do not seal properly in the ear canal or muffs do not seal uniformly against the head around the pinna. The causes of poor HPD sealing are:



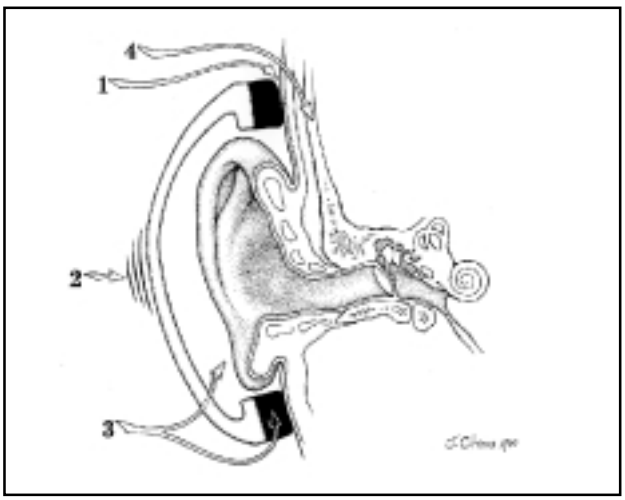


FIGURE 3. Illustrations of the 4 Paths by Which Sound Reaches the Occluded Ear.

1. Comfort - In most situations the better the fit of a HPD, the poorer the comfort. Inserts must be snugly fitted into the canal and earmuff cups must be tightly pressed against the head. This is not conducive to comfort and although some employees may adapt, many will not. This is why it is important to select several hearing protectors (generally 1 muff and 2 earplugs) from the more comfortable available HPDs and to encourage the employee to make the final decision as to which he will use.

2. Utilization - Due to poor comfort, poor motivation or poor training, or user problems, earplugs may be improperly inserted and earmuffs may be improperly adjusted.

3. Fit - All HPDs must be properly fitted when they are initially dispensed. For multi-sized premolded inserts a suitably sized earplug must also be selected during this fitting procedure. Companies must stock all available sizes of multi-sized earplugs and must be willing to use different size plugs for an employee's two ears, this latter situation occurring in perhaps 2-10% of the population. For example, stocking only 3 of the 5 available sizes of the V51-R will reduce the percentage of the population fitable with that device from ≅ 95% to ≅ 85%. The correct size pre-molded insert will always be a compromise between a device that is too large and therefore uncomfortable, and a device that is too small and therefore provides poor protection. The appropriate compromise can often times be achieved, but only with care and skill.

4. Compatibility - Not all HPDs are equally suited for all ear canal and head shapes. Certain head contours cannot be fitted by any available muffs and some ear canals have shapes that may only be fitable with certain inserts or canal caps or sometimes not at all. Earmuffs can only work well when their cushions properly seal on the head. Eyeglasses, sideburns, or long or bushy hair underneath cushions will prevent this and will reduce attenuation by varying amounts.

5. Readjustment - HPDs can work loose or be jarred out of position during the day. It must be remembered that laboratory tests require the subject to carefully adjust a device prior to testing. Under typical use, wearers will eat, talk, move about and may be bumped or jostled, resulting in jaw motion and possible perspiration. These activities can cause muff cushions to break their seal with the head and cause certain inserts to work loose.[10,11] Premolded inserts tend to exhibit this problem, whereas custom molded and expandable foam plugs tend to more effectively maintain their position in the ear canal.

6. Deterioration - Even when properly used, hearing protectors wear out. Some pre-molded plugs shrink and/or harden when continuously exposed to ear canal wax and perspiration. This may occur in as little as three weeks. Flanges can break off and plugs may crack.[12,13] Custom earmolds may crack, or the ear canal may gradually change shape with time, so that the molds no longer fit properly. Earmuff cushions also harden and crack or can become permanently deformed and headbands may lose their ten-

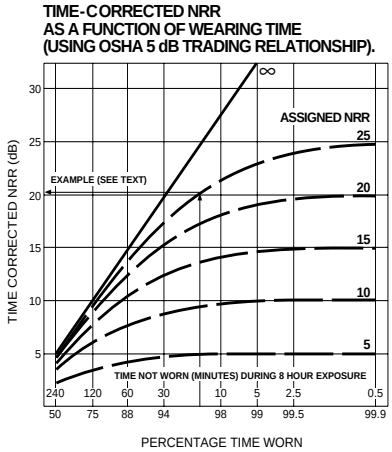


Figure 4

sion. Therefore it is important to inspect or reissue ''permanent'' HPDs on a regular basis. This may be 2-12 times per year or more, depending upon the HPDs that are utilized.

7. Abuse - Employees often modify HPDs to improve comfort at the expense of protection.[12,13,14] These techniques include springing earmuff headbands to reduce the tension, cutting flanges off of premolded inserts, drilling holes thru plugs or muffs, removing the canal portion of custom earmolds, or deliberately obtaining undersized HPDs.

Protection vs. Percentage Time Worn

The HPD RW utilization problems outlined in the preceding section explain why the RW attenuation of HPDs is so much lower than typical manufacturers' laboratory data would indicate (as was extensively discussed in EARLog # 4[1]). In addition to this problem we must contend with the possibility that employees, regardless of how well they wear an HPD, may not wear it during their entire work-shift or period of noise exposure. This will reduce their effective daily protection.

Noise induced hearing loss has been shown to be a function of the cumulative A-weighted noise exposure incident upon the ears.[15,16] Adherents of this theory propose that the hearing levels of a noise exposed population can be estimated from a knowledge of their equivalent continuous noise exposure level (L_{eq}). The L_{eq} is the level of continuous A-weighted noise that would cause the same sound energy to be experienced in an 8-hour day, as resulted from the actual noise exposure. This leads to the 3 dB trading relationship, that is, if the exposure level is increased by 3 dB, the exposure duration must be reduced by 1/2. A similar approach is embodied in the U.S. Occupational Safety and Health Act[17], except that the trading relationship is 5 dB. The implications of the cumulative energy theory with regards to the protection afforded by HPDs, were first discussed by Else.[18] They are presented graphically in Figure 4, with suitable modifications to conform with the OSHA 5 dB trading relationship.

The data in Figure 4 can be utilized to determine the Time Corrected Noise Reduction Rating (NRR) as a function of the percentage of time that the HPD is worn in the noise. We first assign an NRR value to the HPD in question - either the manufacturers' labeled NRR or preferably a RW estimated NRR. If, for example, the HPD had an assigned NRR = 25, then its Time Corrected NRR would be only 20 dB if it was not worn for just 15 minutes during each 8 hour noise exposure. This clearly demonstrates that HPDs must be comfortable enough to be worn properly for extended periods. Attenuation and comfort must both be considered when selecting an HPD.

Neither low attenuation nor low comfort devices are acceptable for standard industrial use. Comfortable, user acceptable HPDs, with real world NRRs suitable for the prevailing environmental sound levels will be necessary to protect your employees' hearing.

References and Footnotes

1. Berger, E.H. - The EARLog series is available upon request from Aearo Company.
2. Von Gierke, H.E., and Brown, D.R. (1953). Protection of the Ear From Noise: Limiting Factors in Benox Report, The Univ. of Chicago. ONR Project NR 144079, Chicago, IL.
3. Nixon, C.W. (1979). Hearing Protective Devices: Ear Protectors in Handbook of Noise Control (2nd Edition),McGraw-Hill, New York, NY.
4. Zwislocki, J. (1957). In Search of the Bone-Conduction Threshold in a Free Sound Field, J. Acoust. Soc. Am., Vol. 29, No. 7, p. 795-804.
5. Gasaway, D.C. (1971). Personal Ear Protection. USAF School of Aerospace Medicine, Report No. SAM-TR-71-13, Brooks AFB, TX.
6. Anderson, C.M.B., and Whittle, L.S. (1971). Physiological Noise and the Missing 6 dB. Acustica, Vol. 24, p. 261-272.
7. Tonndorf, J. (1972). Bone Conduction in *Foundations of Modern Auditory Theory, Vol. II*, Academic Press, New York NY.
8. Gorman, A. G. (1980). New Design Concepts in Personal Hearing Protectors presented at the International Symposium on Personal Hearing Protection in Industry, Toronto, Canada.
9. Data from E-A-RCAL℠ Laboratory experiments in progress.
10. Maas, R.B. (1972). Industrial Noise and Hearing Conservation in *Handbook of Clinical Audiology* (1st Edition), Williams and Wilkins Co., Baltimore, MD.
11. Ohlin, D. (1975). Personal Hearing Protective Devices: Fitting, Care and Use. U.S. Army Environmental Hygiene Agency, Report No. AD-AO21 408, Aberdeen Proving Ground, MD.
12. Riko, K., and Alberti, P.W. (1980). How Ear Protectors Fail: A Practical Guide presented at the International Symposium of Personal Hearing Protection in Industry, Toronto, Ontario.
13. Royster, L.H., and Holder, S.R. (1980). Personal Hearing Protectors: Problems Associated with the Hearing Protection Phase of the Hearing Conservation Program presented at the International Symposium on Personal Hearing Protection in Industry, Toronto, Ontario.
14. Mellard, J.M., Doyle, T.J., and Miller, M.H. (1978). Employee Education - The Key to Effective Hearing Conservation. Sound and Vibration, Vol. 12, No. 1, p. 24-29.
15. Robinson, D.W. (1971). Estimating the Risk of Hearing Loss Due to Exposure to Continuous Noise in Occupational Hearing Loss, Academic Press, New York, NY.
16. Atherly, G.R.C., and Martin, A.M. (1971). Equivalent-Continuous Noise Level as a Measure of Injury from Impact and Impulse Noise. Ann. Occup. Hyg., Vol. 14, p. 11-28.
17. OSHA (1971). Occupational Safety and Health Act, Federal Register, Vol. 36, No. 105, 29CFR1910.95.
18. Else, D. (1973). A Note on the Protection Afforded by Hearing Protectors - Implications of the Energy Principle. Ann. Occup. Hyg., Vol. 16, p. 81-83.

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Eighth in a comprehensive series of technical monographs covering topics related to hearing and hearing protection.

Responses to Questions and Complaints Regarding Hearing and Hearing Protection (Part I)

BY ELLIOTT H. BERGER
Senior Scientist, Auditory Research

The most recent installments of the EARLog series #6 and #7[1], focused on concepts and techniques that have been successfully used to motivate management and employees alike, to actively support and participate in hearing conservation programs. We stressed that the program administrators must sincerely and accurately deal with questions and complaints regarding the utilization of hearing protection devices (HPDs) and the purpose of the hearing conservation program. What follows is a summary of the more common areas of concern that are expressed by supervisors and employees, and information that can provide the basis for appropriate responses.

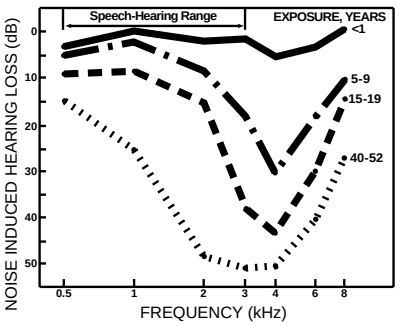
Complaint:
Hearing protectors are uncomfortable.

Response:
HPDs are often uncomfortable initially, but hearing loss due to noise exposure is "uncomfortable" permanently. Like a new pair of shoes or glasses, hearing protectors do require a reasonable period of adjustment. Since not all hearing protectors adapt equally well to all head shapes and ear canals, it is important to give the employee the final choice in what he or she will wear. If after a couple of weeks of daily use the employee is still experiencing difficulties or discomfort, the protector should be resized and/or refitted, or another hearing protector should be issued.

Excuse:
I don't need hearing protection; I am used to the noise.

Response:
Ears do not get used to noise - they "get deaf" (and unfortunately a deafened ear may often *seem* to get used to the noise). Repeated exposure to noise does not toughen ears nor does having an existing noise induced hearing loss prevent you from losing the hearing you have left. Although individual susceptibility to hearing loss from noise exposure varies widely, there are currently no standardized tests that can detect the more noise sensitive members of the population.

ILLUSTRATION OF THE DEVELOPMENT OF NOISE INDUCED HEARING LOSS*



*All exposure levels were approximately 100 dB SPL
(After Taylor, et al.[2])

Figure 1

Question:
I've already lost some or most of my hearing; why should I have to wear hearing protection?

Response:
The existence of a noise induced hearing loss does not protect one from losing further hearing due to noise exposure. In Figure 1, we have illustrated the typical progressive nature of noise induced hearing loss. Initially we see that hearing is damaged in the higher frequencies and as the unprotected exposures continue, this damage spreads to the lower frequencies, eventually affecting those essential to the understanding of speech (500 Hz to approximately 3000 Hz). Although HPDs cannot restore a noise induced hearing loss, which by its nature is permanent and irreversible, they should prevent additional losses from being incurred. Furthermore, proper use of HPDs will prevent employees from developing a temporary hearing loss, and allow existing temporary losses to recover before they become permanent.

Complaint:
I can't hear my fellow workers if I wear hearing protectors.

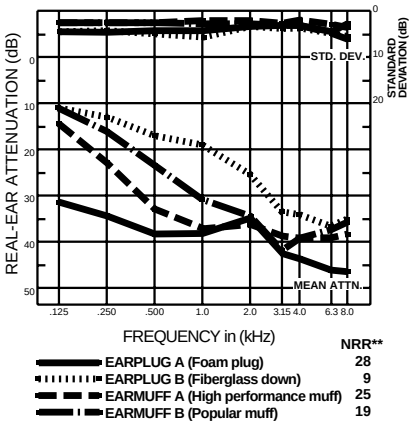
Response[3]:
When the ear is bombarded with high level sound, it overloads and distorts, reducing its ability to accurately discriminate different sounds. Wearing HPDs reduces the overall sound levels so that the ear can operate more efficiently. The effect is similar to the improved vision that sunglasses provide in very bright, high-glare conditions.

For those with normal hearing, HPDs will usually provide improved communications when sound levels are greater than approximately 85 dBA. For moderate to severely hearing impaired individuals, the situation is more complicated; for them, hearing protectors may not provide a communications benefit and actually be a liability. But, if these individuals do not protect their hearing, they may suffer additional impairment and then will have even greater difficulty communicating regardless of noise level.

Complaint:
My machine sounds different to me when I wear hearing protectors.

Response:
True, machines will sound different, but for the reasons outlined above, most employees will still be able to effectively monitor their operation. Once employees

REAL-EAR ATTENUATION OF TWO EARPLUGS AND TWO EARMUFFS*



*All data from E•A•RCAL℠ Acoustical Laboratory.
**Noise Reduction Rating per U.S. EPA

Figure 2

become accustomed to the new sound of their machine, changes in its operation will usually be as easy to detect as without the HPD. Also, since they won't be acquiring progressively increasing amounts of temporary hearing loss throughout the day, employees will be able to hear their machines as well at the end of their shift as when they started in the morning.

Question:
Do earmuffs block out noise better than earplugs?

Response:
No. The misconception that earmuffs are better than earplugs at reducing noise is partly due to the "bigger is better" school of thought. Actually, whether or not an earmuff or an earplug is better is dependent upon the device and user in question.

In Figure 2, the real-ear attenuation data for two muffs and two plugs are plotted. The data are all from one laboratory. Earplug A and earmuff A are among the best commercially available HPDs this facility has ever tested, whereas earplug B is a low attenuation insert and earmuff B is a typical "popular" model. Notice that the better earplug outperforms the better earmuff at all frequencies except 2.0 kHz, where the earmuff offers approximately a 2 dB advantage. But both earmuffs outperform earplug B at all frequencies. Thus although some earmuffs do outperform some ear plugs, it is not true to state that all earmuffs outperform all earplugs.

It is important to remember that although the above discussion focused on attenuation, other factors such as comfort and the intended application significantly affect the choice of a muff or a plug for a particular situation.

Question:
Can earplugs cause ear infection?

Response:
Based on our experience during the past decade, and information gleaned from consultation with experts in the field of otology and audiology [4,5] as well as data from an ongoing survey of U.S. industries [6] it appears that the likelihood of earplugs causing outer ear infections (otitis externa) is minimal. Although it would seem that placing a dirty or gritty foreign object in the ear canal could easily lead to irritation or infection, the data from existing HCPs seem to indicate that the external ear is fairly resistant to such abuse. Nevertheless, cleanliness should be stressed and certain individuals such as diabetics or others who are prone to infection should be more carefully monitored.

When an ear infection is reported, earplugs should not necessarily be assigned the blame. Other causative agents may be [7] excessive cleaning of the ear, recreational water sports, habitual scratching and digging at the ears with fingernails or other objects, environmental contaminants, and systemic conditions such as anemia, vitamin deficiencies, endocrine disorders, and various forms of dermatitis.

Question:
Once I put on my hearing protector, can I forget about it until I take it off for my break?

Response:
No. Hearing protectors may work loose or be jostled out of position and need readjustment. Certain pre-molded and user molded inserts are particularly prone to this problem and must be periodically reinserted or reseated [8,9]. Properly fitted custom ear molds and user formable foam earplugs are among those devices that are best at maintaining position throughout the use period.

Question:
Will I hurt my ears if I blow my nose while wearing an earplug?

Response:
No. Since an earplug is inserted in the external ear canal, which is separated from the middle ear by a membrane (the eardrum), it will not affect the pressure changes in the middle ear which may arise due to blowing of the nose. Sometimes, if the eustachian tube, which vents the middle ear to the back of the throat, is blocked or otherwise not functioning properly air or fluids can be forced into the middle ear and cause discomfort or other problems. However, this will not be affected or aggravated by the use of earplugs.

In EARLog #9 we will continue this dialogue. Additional reference materials are listed below [9, 10, 11].

References and Footnotes

1. Berger, E.H. - The EARLog Series is available upon request from Aearo Company.
2. Taylor, W., Pearson, J., Mair, A., and Burns, W. (1965). Study of Noise and Hearing in Jute Weaving. J. Acoust. Soc. Am., Vol. 38, 113-120.
3. For more details see EARLog #3. The Effects of Hearing Protectors on Auditory Communications.
4. Gasaway, D.C. (1981). Personal Communication.
5. Ohlin, D. (1981). Personal Communcation.
6. Royster, L.H. and Royster, J.D. (1984). "Hearing Protection Utilization: Survey Results Across the USA," J. Acoust. Soc. Am. Suppl. 1, 76, S43.
7. Caruso, V. G. and Meyerhoff, W.L. (1980). Trauma and Infections of the External Ear, in *Otolaryngology*, edited by M.M. Paparella and D.A. Shumrick. W.B. Saunders Co., Philadelphia, PA.
8. Berger, E. H. (1981). Details of Real World Hearing Protector Performance as Measured in the Laboratory. Proc. Noise-Con 81, Noise Control Foundation, Poughkeepsie, NY.
9. Maas, R.B. (1972). Industrial Noise and Hearing Conservation in *Handbook of Clinical Audiology*, edited by J. Katz, William and Wilkins, Co., Baltimore, MD.
10. Council for Accreditation in Occupational Hearing Conservation (1978). *CAOHC Manual*, edited by M.H. Miller. Fischler's Printing, Cherry Hill, NJ.
11. Carroll, C., Crolley, N. and Holder, S. R. (1980). A Panel Discussion of Observed Problems Associated with the Wearing of Hearing Protection Devices by Employees in Industrial Environments. Proc. of a special session on the Evaluation and Utilization of Hearing Protection Devices (HPDs) in Industry, presented at the Spring 1980 meeting of the North Carolina Acoustical Society, edited by L.H. Royster. D.H. Hill Library, North Carolina State Univ., Raleigh, NC.

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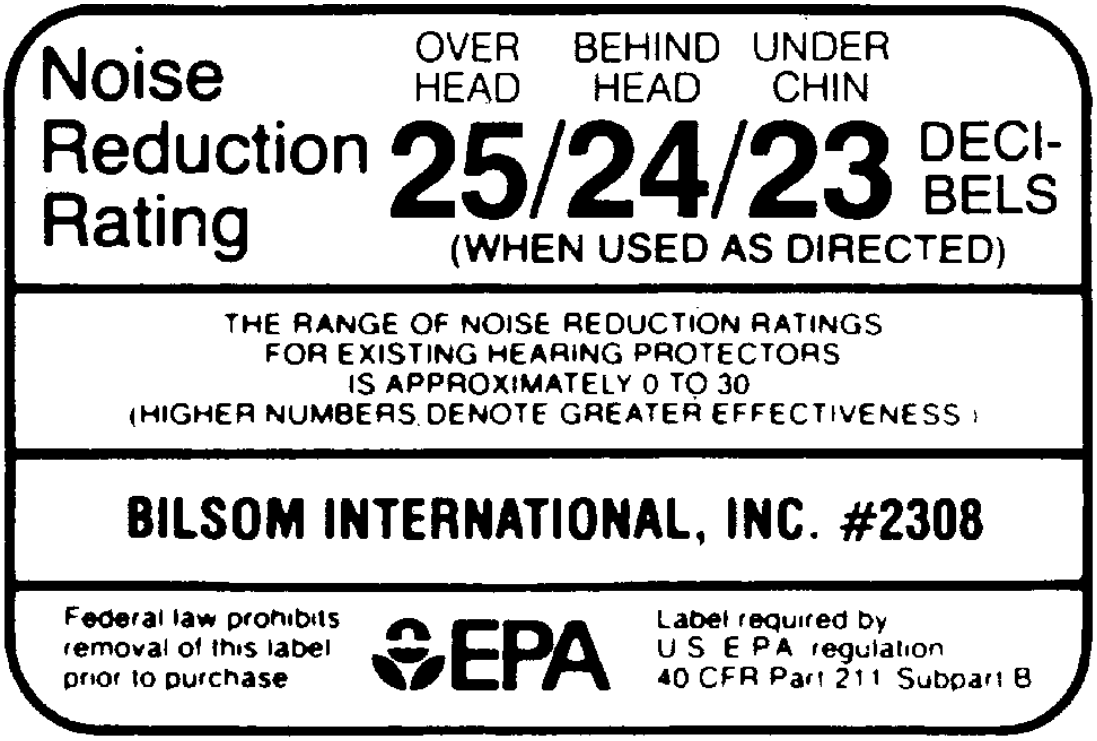
Appendix V

Noise reduction ratings (NRR)

A regulation adopted by the Environmental Protection Agency (EPA) in 1979 requires manufacturers to affix labels to products that produce noise capble of adversely affecting public health or welfare and to products that are sold to reduce noise.

The labels for noise reduction products bear a Noise Reduction Rating (NRR). This is a number giving a measure of the product's effectiveness in reducing noise. The label also provides the range of NRR for competing products. The higher the NRR, the more effective the product. An example label is included below.



Any hearing protection device may be used, provided it supplies sufficient noise attenuation to the inner ear. It is best to provide several types and brands and let the workers choose those that are the most comfortable. Other variables such as cost, durability (shelf and use life) and sanitation characteristics should be considered, along with potential interferences such as eyeglasses and hair.

To determine if hearing protectors reduce noise exposure levels at the inner ear of the employee, use any of the calculation methods listed below or other methods approved by the director.

1. When using a sound level meter set on the C-weighting network:

    a. Obtain a representative sample of the C-weighted sound levels in the employee's environment and compute the 8-hour TWA.

    b. Subtract the NRR from the C-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

2. When using a sound level meter set to the A-weighting network:

    a. Obtain the employee's A-weighted TWA.

    b. Subtract 7 dB from the NRR.

    c. Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

3. When using a dosimeter:

    a. Convert the A-weighted dose to TWA. (See the conversation table in Appendix VI.)

    b. Subtract 7 dB from the NRR.

    c. Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

PART K
HEARING CONSERVATION

WAC

WAC 296-62-09015 Hearing conservation. The employer shall administer a continuing effective hearing conservation program, as described in WAC 296-62-09015 through 296-62-09055 whenever employee noise exposures equal or exceed an 8-hour time-weighted average (TWA) sound level of 85 decibels (dB) measured on the A-scale weighting at slow response or, equivalently, a noise dose of fifty percent. For purposes of the hearing conservation program, employee noise exposures shall be computed in accordance with WAC 296-62-09055, Appendix E: Noise exposure computation, without regard to any attenuation provided by the use of personal protective equipment.
[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09015, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09015, filed 1/15/82.]

WAC 296-62-09017 Definitions. These definitions apply to the following terms as used in WAC 296-62-09015 through 296-62-09055.

(1) **Audiogram** - A chart, graph, or table resulting from an audiometric test showing an individual's hearing threshold levels as a function of frequency.

(2) **Audiologist** - A professional, specializing in the study and rehabilitation of hearing, who is certified by the American Speech, Hearing, and Language Association or licensed by a state board of examiners.

(3) **Baseline audiogram** - The audiogram against which future audiograms are compared.

(4) **Criterion sound level** - A sound level of 90 decibels.

(5) **Decibel (dB)** - Unit of measurement of sound level.

(6) **Hertz (Hz)** - Unit of measurement of frequency, numerically equal to cycles per second.

WAC 296-62-09017 (Cont.)

(7) **Impulsive or impact noise** - Noise levels which involve maxima at intervals greater than one second. Where the intervals are less than one second, the noise levels shall be considered continuous.

(8) **Medical pathology** - A disorder or disease. For purposes of this regulation, a condition or disease affecting the ear, which should be treated by a physician specialist.

(9) **Noise dose** - The ratio, expressed as a percentage, of (a) the time integral, over a stated time or event, of the 0.6 power of the measured slow exponential time-averaged, squared A-weighted sound pressure and (b) the product of the criterion duration (8 hours) and the 0.6 power of the squared sound pressure corresponding to the criterion sound level (90 dB).

(10) **Noise dosimeter** - An instrument that integrates a function of sound pressure over a period of time in such a manner that it directly indicates a noise dose.

(11) **Otolaryngologist** - A physician specializing in diagnosis and treatment of disorders of the ear, nose and throat.

(12) **Representative exposure** - Measurements of an employee's noise dose or 8-hour time-weighted average sound level that the employer deems to be representative of the exposure of other employees in the workplace.

(13) **Standard threshold shift** - A hearing level change, relative to the baseline audiogram, of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear.

(14) **Sound level** - Ten times the common logarithm of the ratio of the the square of the measured A-weighted sound pressure to the square of the standard reference pressure of 20 micropascals. Unit: Decibels (dB). For use with this regulation, slow time response, in accordance with ANSI S1.4-1971 (R1976), is required unless specifically specified otherwise.

(15) **Sound level meter** - An instrument for the measurement of sound level.

(16) Time-weighted average sound level - That sound level, which if constant over an 8-hour period, would result in the same noise dose as if measured in the time varying noise level environment.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09017, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09017, filed 1/15/82.]

WAC 296-62-09019 Monitoring.

(1) When reasonable information indicates that any employee's exposure may equal or exceed an 8-hour time-weighted average of 85 dBA, the employer shall obtain individual or representative exposure measurements for all employees who may be exposed at or above that level.

(2) The sampling strategy shall be designed to identify all employees required to be included in the hearing conservation program and to enable the proper selection of hearing protectors.

(3) Where circumstances such as high worker mobility, significant variations in sound level, or a significant component of impulse noise exist, the employer shall use representative personal sampling to comply with the monitoring requirements of this section unless the employer can establish that area sampling produces equivalent results.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09019, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09019, filed 1/15/82.]

WAC 296-62-09021 Method of noise measurement.

(1) Noise dosimeters which comply, as a minimum, with the provisions of subdivision (1)(a) of this section or sound level meters which comply, as a minimum, with the provisions of subdivision (1)(b) of this section shall be used whenever employee exposures are evaluated for the purpose of complying with WAC 296-62-09015 through 296-62-09055.

(a) Dosimeters. Dosimeters shall meet the Class 2A-90/80-5 requirements of the American National Standard Specification for Personal Noise Dosimeters, S1.25-1978.

(b) Sound level meters. Sound level meters shall meet the Type 2 requirements of the American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976).

(2) All continuous, intermittent, and impulsive sound levels from 80 dBA to 130 dBA shall be integrated into the exposure computation.

(3) Monitoring shall be repeated whenever a change in production, process, equipment or controls increases noise exposures to the extent that:

(a) Additional employees may be exposed at or above an 8-hour time-weighted average of 85 dBA; or

(b) The attenuation provided by hearing protectors being used by employees may be rendered inadequate to meet the requirements of WAC 296-62-09033.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09021, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09021, filed 1/15/82.]

WAC 296-62-09023 Calibration of monitoring equipment. Dosimeters and sound level meters used to monitor employee noise exposure shall be calibrated using the instrument manufacturer's calibration instructions before and after each day's use.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09023, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09023, filed 1/15/82.]

WAC 296-62-09024 Employee notification. The employer shall notify each employee exposed at or above an 8-hour time-weighted average of 85 dBA of the results of the monitoring.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09024, filed 11/30/83.]

WAC 296-62-09025 Observation of monitoring. The employer shall provide affected employees or their representatives with an opportunity to observe any measurements of employee noise exposure which are conducted pursuant to WAC 296-62-09019.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 82-03-023 (Order 82-1), 296-62-09025, filed 1/15/82.]

WAC 296-62-09026 Noise control.

(1) Whenever employee noise exposures equal or exceed an 8-hour time-weighted average of 90 dBA, feasible administrative or engineering controls shall be utilized.

(2) Upon request, the employer shall prepare and submit a written compliance plan to the director or his/her designee. This plan must include a description of the manner in which compliance will be achieved with respect to cited violations of WAC 296-62-09026(1) and shall include proposed abatement methods, anticipated completion dates, and provision for progress reports to the director or his/her designee.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09026, filed 11/30/83.]

WAC 296-62-09027 Audiometric testing program.

(1) The employer shall establish and maintain a mandatory audiometric testing program as provided in this section for all employees whose exposures equal or exceed an 8-hour time-weighted average of 85 dBA.

(2) The program shall be provided at no cost to employees.

(3) Audiometric tests shall be performed by a licensed or certified audiologist, otolaryngologist, or other qualified physician, or by a technician who is certified by the Council of Accreditation in Occupational Hearing Conservation. A technician who performs audiometric tests must be responsible to an audiologist, otolaryngologist or other qualified physician.

(4) All audiograms obtained pursuant to this section shall meet the requirements of WAC 296-62-09047, Appendix A: Audiometric measuring instruments.

(5) **Baseline audiogram.**

(a) Prior to or within 180 days after an employee's first exposure to noise at or above a time-weighted average of 85 dBA, the employer shall establish for each employee so exposed a valid baseline audiogram against which subsequent audiograms can be compared. Employers who utilize mobile test units are allowed up to one year to obtain a valid baseline audiogram for each exposed employee, provided that each employee so exposed shall be trained and shall wear suitable hearing protectors in accordance with WAC 296-62-09015 through 296-62-09055.

(b) Testing to establish a baseline audiogram shall be preceded by at least 14 hours without exposure to workplace noise.

This may be accomplished by use of hearing protectors; however, the employer shall notify employees of the need to avoid high levels of nonoccupational noise exposure during the 14-hour period immediately preceding the audiometric examination.

(6) **Annual audiogram.**

(a) At least annually (i.e. every 12-month interval) after obtaining the baseline audiogram, the employer shall obtain a new audiogram for each employee exposed at or above a time-weighted average of 85 dBA.

(b) Annual audiometric testing may be conducted at any time during the workshift.

(7) **Evaluation of audiogram.**

(a) Each employee's annual audiogram shall be compared to that employee's baseline audiogram to determine if a standard threshold shift has occurred. This comparison may be made by a certified audiometric technician.

(b) If the annual audiogram indicates that an employee has suffered a standard threshold shift, the employer may obtain a retest within 30 days and consider the results of the retest as the annual audiogram.

(c) An audiologist, otolaryngologist or other qualified physician shall review audiograms which indicate a standard threshold shift to determine whether there is need for further evaluation. The employer shall provide to the person performing this evaluation the following information:

WAC 296-62-09027 (Cont.)

(i) A copy of the requirements for hearing conservation as set forth in WAC 296-62-09015 through 296-62-09055;

(ii) The baseline audiogram and most recent audiogram of the employee to be evaluated;

(iii) Measurements of background sound pressure levels in the audiometric test room as required in WAC 296-62-09049, Appendix B: Audiometric test rooms; and

(iv) Records of audiometer calibrations required by WAC 296-62-09029(5).

(d) Inform each employee of the results of his/her audiometric test and whether or not there has been a hearing level decrease or improvement since his/her previous test.

(8) **Follow-up procedures.** If a comparison of the annual audiogram to the baseline audiogram indicates a standard threshold shift, the employer shall ensure that the following steps are taken:

(a) Employees not using hearing protectors shall be fitted with hearing protectors, trained in their use and care, and required to use them.

(b) Employees already using hearing protectors shall be refitted and retrained in the use of hearing protectors and provided with hearing protectors offering greater attenuation if necessary.

(c) Inform the employee in writing, within 21 days of the determination, of the existence of a standard threshold shift;

(d) Refer the employee, at no cost to the employee, for a clinical audiological evaluation or an otological examination, as appropriate, if additional testing is necessary or if the employer suspects that a medical pathology of the ear (as defined in WAC 296-62-09017) is caused or aggravated by the wearing of hearing protectors; and

(e) Inform the employee of the need for an otological examination if a medical pathology of the ear which is unrelated to the use of hearing protectors is suspected.

(9) **Revised baseline.** An annual audiogram may be substituted for the baseline audiogram when, in the judgment of the audiologist, otolaryngologist or other qualified physician who is evaluating the audiogram:

(a) The standard threshold shift revealed by the audiogram is persistent; or

(b) The hearing threshold shown in the annual audiogram indicates significant improvement over the baseline audiogram.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09027, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09027, filed 1/15/82.]

WAC 296-62-09029 Audiometric test requirements.

(1) Audiometric tests shall be pure tone, air conduction, hearing threshold examinations, with test frequencies including as a minimum 500, 1000, 2000, 3000, 4000, and 6000 Hz. Tests at each frequency shall be taken separately for each ear.

(2) Audiometric tests shall be conducted with audiometers (including microprocessor audiometers) that meet the specifications of, and are maintained and used in accordance with, American National Standard Specification for Audiometers, S3.6-1969(R1973).

WAC 296-62-09029 (Cont.)

(3) Pulsed-tone and self-recording audiometers, if used, shall meet the requirements specified in WAC 296-62-09047, Appendix A: Audiometric measuring instruments.

(4) Audiometric examinations shall be administered in a room meeting the requirements listed in WAC 296-62-09049, Appendix B: Audiometric test rooms.

(5) **Audiometer calibration.**

(a) The functional operation of the audiometer shall be checked before each day's use by testing a person with known, stable hearing thresholds, and by listening to the audiometer's output to make sure that the output is free from distorted or unwanted sounds. Deviations of 10 dB or greater shall require an acoustic calibration.

(b) Audiometer calibration shall be checked acoustically at least annually in accordance with WAC 296-62-09051, Appendix C: Acoustic calibration of audiometers. Test frequencies below 500 Hz and above 6000 Hz may be omitted from this check.

(c) An exhaustive calibration shall be performed at least every two years in accordance with sections 4.1.2; 4.1.3; 4.1.4.3; 4.2; 4.4.1; 4.4.2; 4.4.3; and 4.5 of the American National Standard Specification for Audiometers, S3.6-1969(R1973). Test frequencies below 500 Hz and above 6000 Hz may be omitted from the calibration.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09029, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09029, filed 1/15/82.]

WAC 296-62-09031 Hearing protectors.

(1) Employers shall make hearing protectors available to all employees exposed to a time-weighted average of 85 dBA or greater at no cost to the employees. Hearing protectors shall be replaced as necessary.

(2) Employers shall ensure that hearing protectors are worn:

(a) By any employee who is exposed to an 8-hour time-weighted average of 85 dBA or greater; or

(b) By any employee who is exposed to noise above 115 dBA; or

(c) By any employee who is exposed to any impulsive or impact noise measured at or above 140 dB peak using an impulse sound level meter set to either the linear or C-scale.

(3) Employees shall be given the opportunity to select their hearing protectors from at least two different types (i.e. molded, self-molded, custom molded, or ear muffs) of suitable hearing protectors provided by the employer.

(4) The employer shall provide training in the use and care of all hearing protectors provided to employees.

(5) The employer shall ensure proper initial fitting and supervise the correct use of all hearing protectors.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09031, filed 11/30/83; 82-13-045 (Order 82-22), 296-62-09031, filed 6/11/82; 82-03-023 (Order 82-1), 296-62-09031, filed 1/15/82.]

WAC 296-62-09033 Hearing protector attenuation.

(1) The employer shall evaluate hearing protector attenuation for the specific noise environments in which the protector will be used by one of the methods described in WAC 296-62-09053, Appendix D: Methods for estimating the adequacy of hearing protector attenuation, or by other methods if approved by the director.

(2) Hearing protectors must attenuate employee exposure at least to a time-weighted average of 85 dBA or below.

(3) The adequacy of hearing protector attenuation shall be re-evaluated whenever employee noise exposures increase to the extent that the hearing protectors provided may no longer provide adequate attenuation. The employer shall provide more effective hearing protectors where necessary.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09033, filed 11/30/83; 82-13-045 (Order 82-22), 296-62-09033, filed 6/11/82; 82-03-023 (Order 82-1), 296-62-09033, filed 1/15/82.]

WAC 296-62-09035 Training program.

(1) The employer shall institute a training program for all employees who are exposed to noise at or above an 8-hour time-weighted average of 85 dBA, and shall ensure employee participation in such program.

(2) The training program shall be repeated annually for each employee included in the hearing conservation program. Information provided in the training program shall be updated to be consistent with changes in protective equipment and work processes.

(3) The employer shall ensure that each employee is informed of the following:

(a) The effects of noise on hearing;

(b) The purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types, and instructions on selection, fitting, use, and care; and

(c) The purpose of audiometric testing, and an explanation of the test procedures.

(d) The right to access to records as specified in WAC 296-62-09041(5).

(4) A written description of the training program instituted shall be maintained by each employer.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09035, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09035, filed 1/15/82.]

WAC 296-62-09037 Access to information and training materials.

(1) The employer shall make available to affected employees or their representatives copies of this standard and shall also post a copy in the workplace.

(2) The employer shall provide to affected employees any informational materials pertaining to this standard that are supplied to the employer by the director.

(3) The employer shall provide, upon request, all materials related to the employer's training and education program pertaining to this standard to the director.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 82-03-023 (Order 82-1), 296-62-09037, filed 1/15/82.]

WAC 296-62-09039 Warning signs.

(1) Signs shall be posted at entrances to or on the periphery of all well defined work areas in which employees may be exposed at or above 115 dBA.

(2) Warning signs shall clearly indicate that the area is a high noise area and that hearing protectors are required.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09039, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09039, filed 1/15/82.]

WAC 296-62-09041 Recordkeeping.

(1) **Exposure measurements.** The employer shall maintain an accurate record of all employee exposure measurements required by this section.

(2) **Audiometric tests.**

(a) The employer shall retain a legible copy of all employee audiograms obtained pursuant to WAC 296-62-09027.

(b) This record shall include:

(i) Name and job classification of the employee;

(ii) Date of the audiogram;

(iii) The examiner's name;

(iv) Date of the last acoustic or exhaustive calibration of the audiometer; and

(v) Employee's most recent noise exposure assessment.

(3) **Audiometric test rooms.** The employer shall maintain accurate records of the measurements of the background sound pressure levels in audiometric test rooms.

(4) **Record retention.** The employer shall retain records required in this section for at least the following periods:

(a) Noise exposure measurement records shall be retained for two years.

(b) Audiometric test records shall be retained for the duration of the affected employee's employment.

(5) **Access to records.** All records required by this section shall be provided upon request to employees, former employees, representatives designated by the individual employee, and the director. The provisions of WAC 296-62-05201 through 296-62-05209 and 296-62-05213 through 296-62-05217 apply to access to records under this section.

(6) **Transfer of records.** If the employer ceases to do business, the employer shall transfer to the successor employer all records required to be maintained by this section, and the successor employer shall retain them for the remainder of the period prescribed in WAC 296-62-09041(4).

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09041, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09041, filed 1/15/82.]

WAC 296-62-09043 Appendices. WAC 296-62-09047, 296-62-09049, 296-62-09051, and 296-62-09053 and 296-62-09055, Appendices A, B, C, D, and E are incorporated as part of this section and the contents of these appendices are mandatory.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09043, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09043, filed 1/15/82.]

WAC 296-62-09045 Effective dates.

(1) WAC 296-62-09015 through 296-62-09053 shall become effective 60 days after filing with the code reviser, unless otherwise noted below.

(2) Monitoring conducted pursuant to WAC 296-62-09019 shall be completed no later than 180 days from the effective date of the standard.

(3) Baseline audiograms required by WAC 296-62-09027 shall be completed no later than December 31, 1982.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 82-03-023 (Order 82-1), 296-62-09045, filed 1/15/82.]

WAC 296-62-09047 Appendix A--Audiometric measuring instruments.

(1) In the event that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.

(2) Self-recording audiometers shall comply with the following requirements:

(a) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least 1/4 inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(b) It shall be possible to set the stylus manually at the 10dB increment lines for calibration purposes.

(c) The slewing rate for the audiometer attenuator shall not be more than 6 dB/sec except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(d) The audiometer shall remain at each required test frequency for 30 seconds (±3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than ±3 seconds.

(e) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at the test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09047, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09047, filed 1/15/82.]

WAC 296-62-09049 Appendix B--Audiometric test rooms. Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table B-1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), and to the Class II requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976).

TABLE B-1					
Maximum Allowable Octave Band Sound Pressure Levels for Audiometric Test Rooms					
Octave band center Frequency (Hz)	500	1000	2000	4000	8000
Sound pressure level (dB)	40	40	47	57	62

[Statutory Authority: RCW 49.17.040 and 49.17.050. 82-03-023 (Order 82-1), 296-62-09049, filed 1/15/82.]

WAC 296-62-09051 Appendix C--Acoustic calibration of audiometers. Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this Appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to determine that the audiometer is within the tolerance permitted by American National Standard Specifications for Audiometers, S3.6-1969(R1973).

(1) **Sound pressure output check.**

(a) Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

(b) Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

(c) Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

(d) At each frequency the readout on the sound level meter should correspond to the levels in Table C-1 or Table C-2, as appropriate, for the type of earphone, in the column entitled “sound level meter reading.”

(2) **Linearity check.**

(a) With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

(b) Measure the sound levels in the coupler at each 10dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

(c) For each 10dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

(d) This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) **Tolerances.**

When any of the measured sound levels deviate from the levels in Table C-1 or Table C-2 by ±3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at 6000 Hz, an exhaustive calibration is required.

Table C-1		
Reference threshold levels for telephonics - TDH 39 earphones		
Frequency, Hz	**Reference Threshold level For TDH-39 Earphones , dB**	**Sound level Meter reading, dB**
500	11.5	81.5
1000	7	77
2000	9	79
3000	10	80
4000	9.5	79.5
6000	15.5	85.5

Table C-2		
Reference threshold levels for telephonics - TDH 49 earphones		
Frequency, Hz	**Reference Threshold level For TDH-49 Earphones, dB**	**Sound level Meter reading, dB**
500	13.5	83.5
1000	7.5	77.5
2000	11	81.0
3000	9.5	79.5
4000	10.5	80.5
6000	13.5	83.5

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09051, filed 11/30/83; 82-13-045 (Order 82-22), 296-62-09051, filed 6/11/82; 82-03-023 (Order 82-1), 296-62-09051, filed 1/15/82.]

WAC 296-62-09053 Appendix D--Methods for estimating the adequacy of hearing protector attenuation.

(1) Hearing protector attenuation must be sufficient to reduce employee exposure to a TWA of 85 dBA.

(2) The most convenient method to use is the noise reduction rating (NRR) developed by the Environmental Protection Agency (EPA). According to EPA regulation, the NRR must be shown on the hearing protector package. The NRR is then related to an individual worker's noise environment in order to assess the adequacy of the attenuation of a given hearing protector. This appendix describes two methods of using the NRR to determine whether a particular hearing protector provides adequate protection within a given exposure environment. Selection between the two procedures is dependent upon the employer's noise measuring instruments.

(3) When using the NRR to assess hearing protector adequacy, one of the following methods must be used:

(a) When using a dosimeter that is capable of making A-weighted measurements:

(i) Convert the A-weighted dose to TWA.

(ii) Subtract 7 dB from the NRR.

(iii) Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(b) When using a sound level meter set to the A-weighting network:

(i) Obtain the employee's A-weighted TWA.

(ii) Subtract 7 dB from the NRR, and subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(4) Other methods may be utilized if they are at least as effective as the NRR if approved by the director.

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09053, filed 11/30/83; 82-03-023 (Order 82-1), 296-62-09053, filed 1/15/82.]

WAC 296-62-09055 Appendix E--Noise exposure computation.

(1) **Computation of employee noise exposure.**

(a) Noise dose is computed using Table E-1 as follows:

(i) When the sound level, L, is constant over the entire work shift, the noise dose, D, in percent, is given by: D=100 C/T where C is the total length of the work day, in hours, and T is the reference duration corresponding to the measured sound level, L, as given in Table E-1 or by the formula shown as a footnote to that table.

(ii) When the workshift noise exposure is composed of two or more periods of noise at different levels, the total noise dose over the work day is given by: $D=100(C_1/T_1+C_2/T_2+... +C_nT_n)$, where C_n indicates the total time of exposure at a specific noise level, and Tn indicates the reference duration for that level as given by Table E-1.

(b) The 8-hour time-weighted average sound level (TWA), in decibels, may be computed from the dose, in percent, by means of the formula: $TWA = 16.61 \log_{10}(D/100)+90$. For an 8-hour workshift with the noise level constant over the entire shift, the TWA is equal to the measured sound level.

(c) A table relating dose and TWA is given in subsection (2) of this section.

Table E-1

A weighted sound level, L (decibel)	Reference duration T (hour)
80	32
81	27.9
82	24.3
83	21.1
84	18.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8
91	7.0
92	6.2
93	5.3
94	4.6
95	4
96	3.5
97	3.0
98	2.6
99	2.3

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Table E-1 (Cont.)	
A weighted sound level, L (decibel)	**Reference duration T (hour)**
100	2
101	1.7
102	1.5
103	1.4
104	1.3
105	1
106	0.87
107	0.76
108	0.66
109	0.57
110	0.5
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11
122	0.095
123	0.082
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031

In the above table the reference duration T, is computed by

$$T = \frac{8}{2^{(L-90)/5}}$$

where L is the measured A-weighted sound level.

(2) **Conversion between "dose" and "8-hour time-weighted average" sound level.**

(a) Compliance with WAC 296-62-09015 through 296-62-09055 of this regulation is determined by the amount of exposure to noise in the workplace. The amount of such exposure is usually measured with an audiodosimeter which gives a readout in terms of "dose." In order to better understand the requirements of these standards, dosimeter readings can be converted to an "8-hour time-weighted average (TWA) sound level."

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(b) In order to convert the reading of a dosimeter into TWA, see Table E-2. This table applies to dosimeters that are set by the manufacturer to calculate dose or percent exposure according to the relationships in Table E-1. So, for example, a dose of 91 percent over an eight-hour day results in a TWA of 89.3 dB, and a dose of 50 percent corresponds to a TWA of 85 dB.

(c) If the dose as read on the dosimeter is less than or greater than the values found in Table E-2, the TWA may be calculated by using the formula: TWA = 16.61 log10 (D/100) + 90 where TWA = 8-hour time-weighted average sound level and D = accumulated dose in percent exposure.

Table E-2

Conversion from "percent noise exposure" or "dose" To "8-hour time weighted average sound level" (TWA)

Dose or percent noise exposure	TWA (dBA)
10	73.4
15	76.3
20	78.4
25	80.0
30	81.3
35	82.4
40	83.2
45	84.2
50	85.0
55	85.7
60	86.3
65	86.9
70	87.4
75	87.9
80	88.4
81	88.5
82	88.6
83	88.7
84	88.7
85	88.8
86	88.9
87	89.0
88	89.1
89	89.2
90	89.2
91	89.3
92	89.4
93	89.5
94	89.6
95	89.6
96	89.7
97	89.8
98	89.9
99	89.9
100	90.0
101	90.1
102	90.1
103	90.2

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Table E-2 (Cont.)	
Conversion from "percent noise exposure" or "dose" To "8-hour time weighted average sound level" (TWA)	
Dose or percent noise exposure	**TWA (dBA)**
104	90.3
105	90.4
106	90.4
107	90.5
108	90.6
109	90.6
110	90.7
111	90.8
112	90.8
113	90.9
114	90.9
115	91.1
116	91.1
117	91.1
118	91.2
119	91.3
120	91.3
125	91.6
130	91.9
135	.92.2
140	92.4
145	92.7
150	92.9
155	93.2
160	93.4
165	93.6
170	93.8
175	94.0
180	94.2
185	94.4
190	94.6
195	94.8
200	95.0
210	95.4
220	95.7
230	96.0
240	96.3
250	96.6
260	96.9
270	97.2
280	97.4
290	97.7
300	97.9
310	98.2
320	98.4
330	98.6
340	98.8

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Table E-2 (Cont.)	
Conversion from "percent noise exposure" or "dose" To "8-hour time weighted average sound level" (TWA)	
Dose or percent noise exposure	**TWA (dBA)**
350	99.0
360	99.2
370	99.4
380	99.6
390	99.8
400	100.0
410	100.2
420	100.4
430	100.5
440	100.7
450	100.8
460	101.0
470	101.2
480	101.3
490	101.5
500	101.6
510	101.8
520	101.9
530	102.0
540	102.2
550	102.3
560	102.4
570	102.6
580	102.7
590	102.8
600	102.9
610	103.0
620	103.2
630	103.3
640	103.4
650	103.5
660	103.6
670	103.7
680	103.8
690	103.9
700	104.0
710	104.1
720	104.2
730	104.3
740	104.4
750	104.5
760	104.6
770	104.7
780	104.8
790	104.9
800	105.0
810	105.1

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Table E-2 (Cont.)	
Conversion from "percent noise exposure" or "dose" To "8-hour time weighted average sound level" (TWA)	
Dose or percent noise exposure	**TWA (dBA)**
820	105.2
830	105.3
840	105.4
850	105.4
860	105.5
870	105.6
880	105.7
890	105.8
900	105.8
910	105.9
920	106.0
930	106.1
940	106.2
950	106.2
960	106.3
970	106.4
980	106.5
990	106.5
999	106.6

[Statutory Authority: RCW 49.17.040 and 49.17.050. 83-24-013 (Order 83-34), 296-62-09055, filed 11/30/83.]

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